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Sedimentary, Magmatic and Ore-forming Responses
to Compressional and Tensional Tectonics: A focus on Africa

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Review Panel

COMMENT ON THE REVIEWING PROCESS

All extended abstracts contained in this volume were subjected to editorial and scientific review. The panel of reviewers is presented below. Reviewers were selected for their expertise in the broadly defined subject areas that correspond with the major sub-themes of the conference.

REVIEW PANEL

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MAGMATISM AND MINERALIZATION IN THE VARDAR ZONE COMPRESSIONAL AREA, SE-EUROPE

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SYNOPSIS
The area of the Vardar Zone has been defined as zone of ophiolite melange, zone of crushing and cataclasts, zone of intensive magmatism from Jurassic to Pliocene and zone of numerous polymetallic ore deposits and occurrences. The Vardar Zone is known as a rift zone but also as a zone of subduction where Jurassic ocean crust was subducted beneath the crystalline schist of the Serbo-Macedonian Massif. Magmatism and mineralizations are of various ages, Jurassic to Pliocene. The main magmatic stages with productive mineralization were generated during the post-subduction period (more precisely during the Alpine orogenesis). Specifically, during the period from Eocene to Pliocene, the Tertiary magmatism is of enormous significance, which has been pointed out as the main reason for the genesis of numerous ore deposits and occurrences of following types: copper-porphyry type, lead-zinc vein and metasomatic type, Sb vein and metasomatic type, Au vein and Carlin type, thallium, molybdenum, tungsten, etc. Ore mineralization has been related to intrusive dacites, andesites and quartzatites. Polymetallic mineralization related to Pliocene magmatism (1.8-6 Ma) in southern parts of the Vardar Zone, is of special interest. Without any doubt this magmatism was a result of the compressional stage in the Vardar Zone during the collision period.

GEOLOGICAL AND METALLOGENIC FEATURES

The Tertiary magmatism in the Dinarides, the Vardar zone and the Serbo-Macedonian massif took place after closure of the Mesozoic ocean basin. This closure is a result of exposure of the Dinaride micro-slab and the Carpatho-Balkanide block with the Serbo-Macedonian massif and collision between these continental segments. The subduction process during the Middle and Upper Jurassic was followed by calc-alkaline magmatism during the Middle and Upper Cretaceous. Further continental collision resulted in thickening of the continental crust and intrusion into the upper envelope, as well as isostatic upliftings. Discontinued compression resulted in temporary melting of the basal parts of the continental crust with variable admixtures of material from the upper envelope. These pulsations and tectono-magmatic activities took place many times during the Oligocene, the Miocene and the Pliocene. Magmatites are distributed in a separate area, most commonly in the middle parts of the arch-dome structures and generally formed volcano-plutonic belts. These granodiorite quartzdiorite to quartzmonzonite magmas formed intrusive rocks of various size and very large to small volcanic complexes. Rock types found on the surface are a result of uplift of individual tectonic blocks as well as the intensity of erosion. Nevertheless, all complexes can be considered as volcano-plutonic, in which erosion either revealed deep intrusive parts or preserved volcanic complexes in some places.

$^{87}Sr/^{86}Sr$ isotope data and ages of magmatic rocks in the area of consideration are presented in Table 1. Evidence that the parent magma was contaminated by material from continental crust, including local contamination by peridotites can be found in the strontium ratios. From the data presented in Table 1, it can be inferred that the Sr ratios of magmatic complexes located in the Vardar zone show rather uniform variability and moderate contamination of magma by crustal material (Sr ratios range from 0.706 to 0.708, but latter values prevail). Increases of Sr ratios are found in the volcanics eastern of the contact zone between the Vardar Zone and the Serbo-Macedonian Massif. These values in the Sasa District are 0.709-0.710.

Some regional metallogenetic units such as the Serbo-Macedonian-Central Anatolian province are associated with the Oligocene-Miocene/Pleistocene calc-alkaline complexes. The origin of these magmatic complexes cannot be unequivocally related to subduction of an oceanic crust and its partial melting, although they are situated in the vicinity of a suture zone, formed after

Table 1 - *The isotopic age and $^{87}Sr/^{86}Sr$ ratio for the Tertiary magmatic rocks from the Vardar Zone Cempressional Area*

	Lokality	Type of rock	Age in m. y	$^{87}Sr/^{86}Sr$
I	Boranja	Granodiorite	32.5-30	0.70815-0.70864
	Golija	Granodiorite	18.02-17.3	-
	Zeljin	Granitoid	24.20	-
	Rogozna	Andesite, dacite	33-27.2	0.7077-0.7066
II	Avala	Latite, andesite,	25.1-23.5	-
	Bukulja	dacite	19-15	0.708
	Brajkovac	Granitoid	30	0.7066
	Cer	Granitoid	30-22	0.708078-0708238
	Straznica (Cer)	Quartz monzonite	18-15	0.7212-0.7213
	Kopaonik	Leucocratic granite	35.6-30.0	-
	Kozuf	Granodiorite	1.8±0.1	-
	Kozuf	Latite,	5.0±0.2	0.708546
	Kozuf	Latite,	6.5±0.2	0.709019
	Kozuf	Q-latite	4.8±0.2	-
		Andesite		
III	Lece	Andesite	29.2	-
	Tulare	Andesite	23.0	-
	Bajlovci	Trachyndesite	32.26	-
	Zletovo	Q-latite	26.5±2.0	0.706318
	Zletovo	Latite	24.7±0.4	-
	Bucim	Andesite, latite	26-24	0.706928
	Borov Dol	Andesite	29	0.706633
	Damjan	Andesite	28.6	0.706633
	Gerakaria	Rhyodacite	31.5	-
	Stratoni (Chakidiki)	Granodiorite	29.6	-
	Skouries	Porphyritic syenite	19	0.7080
IV	Toranica	Andesite	25-14	0.709785
	Sasa	Andesite, latite	14.0±3.0	0.710641
	Sasa	Q-latite	24.0±3.0	0.710244

the closure of the Vardar-Izmir Ankara ocean. It is more likely, but still as a tentative model, that, the widespread calc-alkaline igneous suites resulted from an anatectic partial melting of the lowermost part of continental crust and that locally even some ophiolites were involved. These processes took place during the late Palaeogene through early Neogene along the Vardar-Izmir-Ankara suture zone, preceeded by uplifting of the central parts of the suture zone owing to lateral compression.

The ore deposits were emplaced in hypabyssal and volcanic levels, later often associated with caldera structures. Some deposits were formed from submarine brines, syngenetic and/or epigenetic with respect to country rocks. They may represent a specific group of deposits developed in this tectonic setting (such as hydrothermal sedimentary deposits of boron minerals, gold/silver-lead/zinc+/-Sb/As/Tl). Some deposits were formed above ophiolites and they contain some elements which were mobilized by hydrothermal solutions passing through ophiolites (gold, PGE, copper). Some metallogenic features of major mineral deposits in the area of consideration are given in Table 2.

Lead-zinc and antimony are the dominant metals in this tectonic setting, but locally copper, gold/silver, thallium, arsenic, molybdenum.

Lead-zinc deposits**.** Various types of lead-zinc sulphide deposits are found: skarn, volcanogenic veins and replacement type, characterized in places by significant vertical extents of mineralization (up to 2000m such as the Trepcha deposits in Yugoslavia), large ore reserves (the Sasa ore field in the Republic of Macedonia contains over 80 million tons of ore of commercial grade) and the Laurion in Greece.

Antimony deposits. Numerous antimony deposits occur in this metallogenic setting, some of which are economically important (the Podrinje district). Apart from monomineral stibnite deposits, there are other associations of metals and minerals such as Sb-As-Tl-Au (Alshar), Sb-W (stibnite-wolframite deposits at Philadelphion in Greece), Sb-Pb/Zn-As (Ruyevac and Rayicheva Gora in Yugoslavia).

Table 2- *Major Genetic Types of Mineral Deposits Related to Volcano-Intrusive Complexes of Calc-alkaline Suites in the Vardar Zone Compressional Area*

Types of ore deposits		**Environments, morphogenetic types of ore bodies**	**Locality, associations of elements/minerals**
ENDOGENE Deposits related to volcano-intrusive complexes of calc-alkaline suites	Deposits related to granitoid complexes (plutonic intrusions) and pegmatite bodies	(i) Pegmatite	(i) Cer, Bukulja: *Sn, W, Nb-Ta*
		(ii) Greisen (veinlets and stockwork-dissemination)	(ii) Boranja, Bukulja: *Sn, W, Nb-Ta*
		(iii) Skarn (lensoid, irregular ore bodies, etc)	(iii) Boranja: *magnetite, Bi, Cu,* Kopaonik: *magnetite, Mo, sheelite, wolastonite,* Rogozna:*Cu and Pb-Zn*, Golija: *W, Cu, Sn, Bi*
		(iv) Hydrothermal veins in volcanics accompanied by impregnations	(iv) Zeljin: *Pb-Zn, Sb, F, hematite;* Cer: *U,* Bukulja: *U*
	Deposits related to subvolcanic intrusions, volcanic rocks and mineralizations related to volcanic structures	(i) Hydrothermal veins in volcanics accompanied by impregnations	(i) Golija: Pb-Zn, U, Rogozna: Pb-Zn, Stave: Sb, (Grasnicka Reka); Lece, Zletovo: Pb, Zn, Au
		(ii) Skarn and replacement type of deposits	(ii) Kosmaj: Pb-Zn, U, Rudnik: Pb, Zn, Bi, Ag, Kopaonik: Trepca (Pb-Zn), Fe-Mn carbonate, Rogozna: Pb-Zn, Belo Brdo: Pb-Zn a.a., Koporic-Stave: Pb-Zn; Damjan (skarn): Fe, Novo Brdo: Pb, Zn, Mn, Ag
		(iii) Impregnation in “hydroquartzite” along contact with serpentinite	(iii) Koporic-Stave: Pb-Zn; Sb, and Pb-Zn sulphide (Rajiceva Gora), Lojane: Sb, As, Tl
		(iv) Porphyry copper	(iv) Tulare, Buchim-Borov Dol, Vati, Skouries a.a.
		(v) Hydrothermal stockwork disseminated mineralization	(v) Avala: Pb-Zn, Hg, Djavolja Varos: Cu, Au, Ag, (Pb, Zn, Mo)
	Low temperature hydrothermal deposits located far away from magmatic complexes	Vein and stockwork disseminated types of deposits	Golija: mainly antimony deposits
EXOGENE (secondary)	Alluvial deposits	Cer, Bukulja: cassiterite Radoscinska reka: detrital magnesite	

Porphyry copper deposits formed occasionally, mostly in the Lece-Chalkidiki zone. They are associated with minor intrusions of calc-alkaline suites, located predominantly around subvolcanic intrusions (Buchim, Skouries, Fisoka) in the volcanics (Borov Dol in the Republic of Macedonia, Kiseli Potok in Yugoslavia).

Porphyry copper deposits formed in this tectonic setting are of small size, locally enriched by gold (Buchim) accompanied by traces of PGE (mostly paladium).

Molybdenum mineralization as disseminated and/or vein types occurs occasionally. Some of these, such as the stockwork-disseminated at Machkatica in Yugoslavia, contain large reserves but low grade. The quartz-molybdenite veins are of small size (the veins in granite near Axiopolis in Greece).

Hydrothermal-sedimentary deposits in Neogene basins were formed from ascending hydrothermal springs at the base of basin of sedimentation. They supplied metal ions and caused a high metal content in the water. This led to the depositional enrichment and formation of ore bodies such as large bedded magnesite deposits, (Bela Stena in Yugoslavia).